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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 661

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. ▼ April 9, 1918

THE MANUFACTURE OF CASEIN FROM BUTTERMILK OR SKIM MILK.[1]

By ARNOLD O. DAHLBERG,[2] *of the Dairy Division.*

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IMPORTANCE OF CASEIN MANUFACTURE TO CREAMERIES.

The utilization of by-products by a large number of small creameries is daily becoming of more economic importance. Because of the ever-increasing competition, the future success of many creameries depends in no small degree upon both the quality of their products and the extent to which by-products may be profitably utilized. The small creameries usually receive a good quality of raw material

[1] Acknowledgment is made of the courtesy of the Robert Gair Co., Brooklyn, N. Y., and the Dill & Collins Co., Philadelphia, for hearty cooperation and assistance in running coating tests on their large commercial machines, which involved considerable inconvenience and expense, but gave valuable information as to the practical value and working properties of the samples submitted. Special thanks are extended to Ernest Hafele and H. A. Sawyer, chemists for the companies mentioned, for their patience and interest in arranging for the various tests and for making it possible to obtain information relative to the application of casein in the paper industry.

The J. A. & W. Bird & Co., Boston; the Casein Manufacturing Co., New York, and the Union Casein Co., Philadelphia, furnished information and data which were of great value in the work.

In the earlier part of this investigation the Bureau of Standards of the Department of Commerce kindly placed at our disposal equipment for investigation on the solubility of casein, and the assistance of F. C. Clark of that bureau in this connection was of value.

[2] The investigation of the manufacture of casein from buttermilk was begun by Dr. F. J. Birchard, formerly of the Dairy Division, and after his departure the work was taken up by the writer.

and probably can obtain greater efficiency through quality rather than quantity. When a good grade of cream is received, not only can a high-quality butter be made, but the buttermilk can be more profitably utilized.

In the past skim-milk casein is the only kind that has been made in large quantities. However, many creameries have a considerable quantity of buttermilk, which is not disposed of to the best advantage, and this by-product can be made to realize a profit to the creamery and produce greater returns to the farmer if it is made into a good grade of casein. It is possible to make profitably a good grade of casein from buttermilk when good raw material is received, provided the buttermilk does not bring exceptional prices for food. It is, of course, advisable to convert the buttermilk into food products when proper markets can be obtained, as greater profits usually can be derived from it in that form. It is not always possible to utilize all the buttermilk to the best advantage as a food product, and it is important to be able to turn the surplus into casein, which is a good-keeping product and finds a ready market. As dried casein of good quality can be marketed in unlimited quantities, its manufacture acts as a safety valve in utilizing any surplus buttermilk or skim milk.

THE MANUFACTURE OF CASEIN FROM BUTTERMILK.

The recovery of casein from buttermilk by the method to be outlined is dependent upon the normal acidity of the buttermilk. Sweet buttermilk must be ripened until the proper degree of acidity has developed. The sour buttermilk from the churn, or that which has developed the required acidity by ripening, is heated sufficiently to cause a rapid separation of the curd and whey. Owing to the fineness of buttermilk curd every precaution must be taken to prevent it from being broken up any finer, which makes handling more difficult. Turning steam directly into the buttermilk has too great a tendency to break the curd up and make handling more difficult. The method devised for heating the buttermilk to obtain a rapid and clear separation of the curd in such manner as to give favorable conditions throughout the rest of the process consists in running it through a steam jet or ejector. In this way the desired temperature can be obtained in a rapid and efficient manner and with very little agitation of the curd. With buttermilk of sufficient acidity there should be no difficulty in getting a good separation at a temperature varying between 115° and 130° F. (46.11° and 54.44° C). (See fig. 1.) The proper temperature to get the characteristic clear and rapid separation of the curd from a given lot of buttermilk can readily be ascertained at the start of a run by catching

samples of the heated buttermilk in a glass tumbler as it comes from the ejector. By varying the temperature, that which will give the best results is determined. At that temperature the curd immediately rises to the top, leaving a clear whey below.

This method is based upon results obtained in devising and putting into operation a practical method for handling the surplus

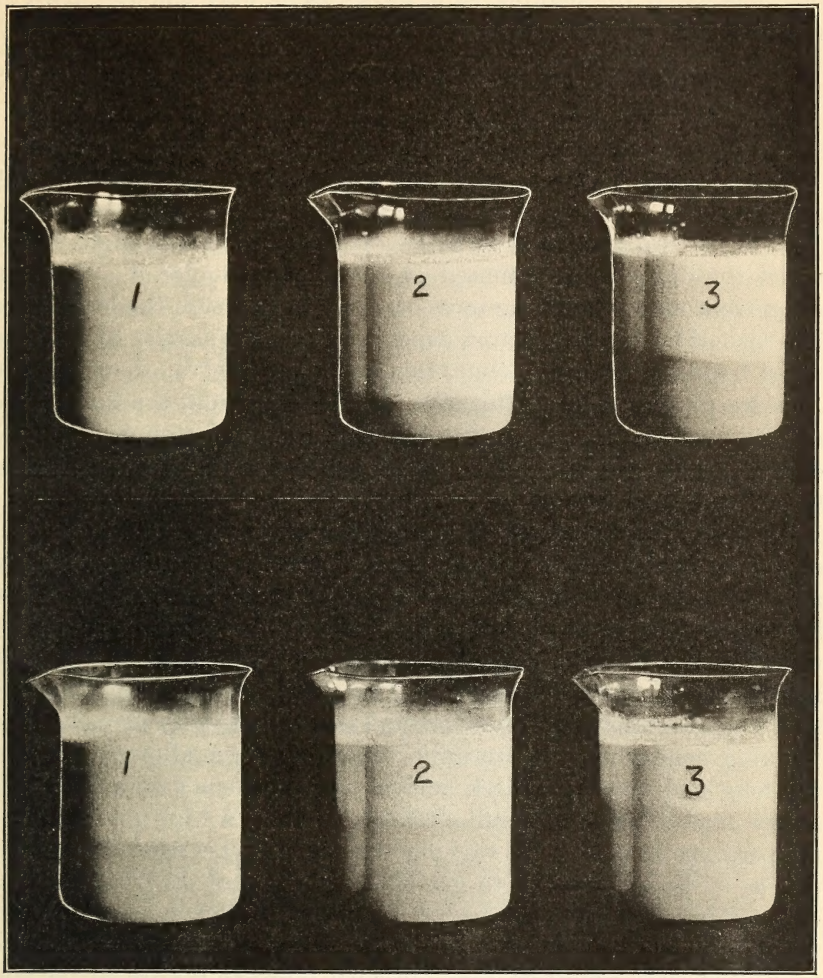

FIG. 1.—Proper heating with the ejector gives a rapid and clear separation. Upper row of beakers shows extent of separation, heating to 115° F. (46.11° C.) at one, two, and five minutes, while lower row shows the same thing heating to 125° F. (51.67° C.)

buttermilk of the Grove City Creamery, Grove City, Pa., operated under the supervision of the Dairy Division, United States Department of Agriculture, and therefore has received a thorough trial in a commercial creamery, where it is giving most satisfactory results. Any creamery with similar raw material, by the applica-

tion of principles within its control, can obtain like results. While the study of the effect of the different factors upon the quality of the casein was carried on with samples made from experimental lots, the directions for manufacturing are derived from observations taken when making the product in a commercial way and under conditions comparable with those of the ordinary creamery. The methods given for making skim-milk casein were likewise tried in a commercial way in the Grove City Creamery.

DIRECTIONS FOR MANUFACTURING BUTTERMILK CASEIN.

PRECIPITATING THE CURD.

The buttermilk from the churn is pumped into a tank elevated sufficiently to allow it to run by gravity through an ejector and from there into another tank below, whose gate valve is high enough to let the drain rack, mounted on casters, run under it. Such arrangement makes handling most convenient and with the least labor. The size of tanks and ejectors depends upon the quantity of material to be handled. To save time, the heating should be done quickly. A valve placed in the buttermilk pipe leading from the tank to the ejector, and one in the steam pipe next to the ejector, permit easy control of the temperature to which the buttermilk must be heated to obtain proper separation.

The temperature necessary to obtain a clear and rapid separation of the curd from a lot of buttermilk depends to some extent upon the acidity, and can be ascertained at first by taking samples of the heated buttermilk as it comes from the ejector. While conclusive data bearing directly upon the degree of acidity required for the most favorable results have not been obtained, an acidity of from 0.65 to 0.80 per cent at the time of precipitation apparently gives the best working conditions. Buttermilk which has been allowed to stand too long and develop a high acidity has a tendency to give a soft, sticky curd difficult to handle, especially when a high precipitating temperature is used. By varying the temperature used, the proper degree of heat necessary to get good results may be obtained. At that temperature the curd begins to rise to the top quickly, leaving the clear whey below. When it comes from the ejector the buttermilk is in such condition that the curd invariably rises to the top. As soon as the curd has massed at the surface, which requires only a few minutes, the greater portion of the whey can be drawn from the bottom of the vat into the cloth-lined drain rack. The clear whey passes through the drain cloth quickly and by gradually closing the gate valve as the curd lowers in the vat, practically all of it can be drained away. When the whey has drained away, the hot curd is placed on the drain racks, ready for washing. Every pos-

sible precaution should be taken in handling the sour buttermilk not to agitate it unnecessarily by pumping or in any other manner, as it breaks the curd up finer and makes handling more difficult.

WASHING THE CURD.

After all of the hot curd has been placed on the drain cloth, it is washed at least twice with cold water, which apparently hardens the curd particles and makes handling easier. The use of a shower-bath spray nozzle attached to the water hose is advantageous in washing the curd, for with it the massed curd can be broken up and washed better. Draining is hastened by giving the drain cloth a quick pull from one side to the other. After a few trials no difficulty should be encountered in peeling the curd clean from the drain cloth in order to afford better drainage surface. The curd is given a thorough soaking each time, care being used to get the whole mass of particles in contact with the water. Under proper conditions the curd drains readily but it always should be allowed to stand a short time between washings. Individual experience will show the best method of washing the curd in the shortest time and still get the desired results.

The number of washings required will depend on the thoroughness with which the work is done. The drain water coming from the pressed curd should test less than .20 per cent acidity, which is possible with two washings if ample time is allowed for each drainage. Continuous attention is unnecessary when the curd is on the drain racks. The greater portion of a man's time during that period is available for other work unless a very large quantity of buttermilk is to be handled. After the last washing the curd is allowed to drain well in order to save time in putting to press. Trouble is encountered in getting a stack of wet curd in press cloths to press evenly, and at the outset it takes up more space in the press.

PRESSING.

A form made of 1-inch surfaced material 20 inches square and 8 inches deep is placed at the bottom of the press rack and lined with two press cloths. After placing in the form the proper quantity of wet curd the cloths are neatly turned over from both sides in a manner to hold the curd securely when pressure is applied, special care being given to the corners, where trouble is most liable to occur. The form is then removed and a dividing board placed on top of the mass of wet curd, when the form can be replaced and the process continued until all the curd has been taken care of. The quantity of wet curd placed in the press cloths depends somewhat on the condition of the curd and can be determined best by experience.

When all the curd is placed in the cloths heavy pressure is applied by means of jackscrews until the following morning or until the curd is sufficiently dry for satisfactory grinding. In case some one is not at the plant all the time some method for maintaining a continuous, heavy pressure must be provided, as the expulsion of moisture from the curd under pressure quickly releases the tension. A satisfactory device for obtaining such pressure can be made easily and added to the regular press rack by means of heavy railway-car springs. When pressure is first applied to the curd a little attention is necessary to get the curd to press evenly; afterwards the jackscrews have to be tightened only occasionally.

GRINDING.

Provided the pressure has been ample, no trouble will be experienced the following morning in properly grinding the curd. The curd should not be taken from the press until it is sufficiently dry for proper grinding and drying. In this condition grinding produces a fine, mealy curd that spreads well and does not adhere in lumps to prevent favorable drying conditions. When sufficient moisture has not been pressed from the curd, serious difficulties are experienced, as it is extremely hard, if not impossible, to grind a wet, soggy curd. After grinding, the curd must be dry and mealy, so that it may be spread easily upon the drying trays and permitted to dry thoroughly and quickly. Ground curd, if wet, can not be spread satisfactorily, and not only adheres in lumps that are very difficult to dry, but in drying they form a hard, impervious, bonelike outside surface, while the interior still remains moist.

The curd should be ground fine enough to allow it to dry rapidly and thoroughly. The importance of the thorough pressing and grinding of the curd can be appreciated readily when consideration is given to the following factors:

Steam for drying is saved.

Finely ground curd gives a lighter colored and much better looking grade of casein as it comes from the drying tunnel.

The curd requires a shorter period of heating.

More curd can be handled in a given time, thus increasing the efficiency of the plant.

There is less wear and tear on the machinery.

PLACING THE GROUND CURD ON THE DRYING TRAYS.

A fine-mesh screening must be used for the drying trays, as the buttermilk casein is very fine and not flaky like that made from skim milk by the addition of commercial acid. The finely ground curd is most easily spread upon the drying trays shortly after grinding. While the work can be done by the usual method of throwing a shovelful of the ground curd on a tray and then spreading it with

the hands, better results can be obtained by the use of a simple shaker screen, similar to those used for screening sand and gravel. A box arrangement that is supplied with ground curd by means of a hopper permits the empty trays to be pushed under the screen. A box of that kind can be quickly made at very little cost and will save time and also spread the curd in a uniform thickness, which affords the best drying conditions. When the curd is not spread uniformly the drying time is increased to the time necessary to dry the thickest parts. As the trays are filled they are stacked upon wooden trucks provided with swivel casters, for convenience in running them in and out of the drier.

DRYING.

The stacked trays, with the curd uniformly spread on each, are run into the tunnel drier where a current of heated air is passed over them. The time required for proper drying depends on:

The condition of the curd.
The uniformity of the spreading on the trays.
The volume and temperature of the air passing over the curd.

The volume and speed of the air current blowing over the curd should not be excessive, but sufficient to carry the moisture off readily. When the air current is too swift much of the fine dried casein is blown off the trays. A temperature of 130° F. (54.44° C.) has apparently no detrimental effect upon the casein and is sufficiently high for all purposes. Casein dried at that temperature comes from the drier in a fine-grained condition and breaks up very easily, while that dried at a higher temperature has more tendency to adhere in one mass and is harder to grind to the same degree of fineness. High temperature results in casein that is more difficult to dissolve, particularly in the presence of greater quantities of fat. High temperatures are also very liable to cause discoloration of the casein, especially when impurities, resulting from either poor raw material or faults in the process of manufacture, are present. A temperature no higher than is necessary and never exceeding 130° F. (54.44° C.) should be used in order to lessen the danger of obtaining a darker colored casein. In order to get a product that will keep well it is important to dry the casein thoroughly before it is removed from the drier. It is an easy matter to ascertain when a properly ground curd is dry, but great care must be exercised in determining when a coarsely ground one is ready to be taken from the drier. Since large particles of curd dry slowly they must be broken or cut in two to find out whether the inside is properly dried. No trouble need be experienced in drying the casein completely within 7 hours at a temperature of 130° F. (54.44° C.), provided the curd has been properly ground and spread upon the trays in the proper manner.

REMOVING DRIED CURD OR CASEIN FROM THE TRAYS.

When the curd has been properly ground and uniformly spread upon the trays the finished casein comes from the drier in good physical condition and it can be collected easily by turning the trays over a bin and giving them a slight jar. If grinding and drying conditions have been unfavorable the casein does not come from the trays so easily, as it does not have the same granular form and has more tendency to stick to the screening. This is especially true in the case of a high-fat buttermilk curd which has not been washed sufficiently to remove the sugar and other soluble impurities.

GRINDING AND PACKING CASEIN.

It is advisable to grind and screen the casein after it comes from the drying tunnel in order that it may be of uniform grain and appearance. In the marketing of casein uniformity is of as much importance from the standpoint of appearance as in the case of other products. Grinding a coarse-grained casein makes the color considerably lighter, which is much desired. For grinding, a small burr-feed grinder gives satisfactory results and can be procured at small expense. The finished casein is placed in strong burlap or grain sacks in which it is shipped to market. Care must be taken, while awaiting shipment, to store the casein in a dry place where, if properly made, it will keep for several months.

YIELD OF BUTTERMILK CASEIN.

Depending upon its physical condition at the time of precipitation, 100 pounds of undiluted buttermilk yields on the average from 2.8 to 3.1 pounds of dried casein. Coagulated buttermilk which has been broken up by mechanical agitation, such as pumping or stirring, gives a very fine curd, much of which is liable to be lost through the drain cloth. In ascertaining the yield, the quantity of water added to the cream in rinsing the vat and utensils should be taken into consideration if correct figures are desired. In many creameries the cream is diluted with an unnecessarily large quantity of water before it reaches the churn, and in such instances the yield of casein, based on the actual weight of the diluted buttermilk, is considerably lower.

COST OF MANUFACTURE.

No definite figures can be given on the cost of manufacturing, as cost-accounting data were not kept when a sufficient quantity of buttermilk was handled to give results applicable to ordinary creamery conditions. The cost of making is governed largely by the volume of business. When, in order to take care of surplus material, only

occasional runs are made, the cost is considerably higher than when the volume of business carried on is sufficient to permit the most efficient and economical use of labor and equipment. If 10,000 or more pounds of buttermilk is handled daily the cost of making dried casein should not exceed 3 cents a pound.

The cost of making casein from skim milk is less than that from buttermilk, as it does not require nearly so much work. Several concerns that were making a large quantity of skim-milk casein regularly estimated that the cost of manufacture was between 1 and $1\frac{1}{2}$ cents a pound, although they had no detailed cost-accounting figures. It is probable that the cost will be more than is ordinarily estimated by those without definite figures, since, in figuring it, the depreciation and the interest on the cost of equipment should be included with the expense of labor, steam, and other items.

EQUIPMENT REQUIRED.

For making buttermilk casein, the necessary apparatus, besides the storage tank and precipitating vat which are already available in most creameries, consists of the following:

Drying tunnel with fan blower and heating coils.
Drying trays.
Trucks for holding the drying trays.
Curd mill.
Curd press.
Press dividing boards.
Drain rack.
Cloths for draining and pressing the curd.

Practically the same equipment is needed for making skim-milk casein, with the exception of the drain rack, which ordinarily is not used.

It is advisable to make the tunnel drier larger than the immediate demands require. When being constructed this can be done at comparatively little additional expense and it allows, without inconvenience, expansion of the plant. The remainder of the equipment can be increased easily at any time.

Many creameries that do not have buttermilk enough to warrant putting in the complete drying apparatus precipitate the curd, press a large part of the moisture out, and sell it in that condition. In that case the curd is received at a central plant where it is ground and dried. If a market can be obtained for the wet curd the only additional apparatus required, besides the vats, are the drain rack, curd press, dividing boards, and the cloths for draining and pressing, all of which are available at comparatively small expense. The item of greatest cost is the apparatus for drying the casein, which consists of the drying tunnel with fan blower and heating coils, drying trays,

trucks to hold the trays, and the curd mill. Several creameries may combine to maintain a central drying plant and ship their green curd to the plant for drying; this is advisable if each plant, because of the small quantity of curd handled, can not afford a complete equipment.

TUNNEL DRIER.

The best type of drier is made of tongue-and-groove boards nailed both sides of the studding, the space between being filled preferably

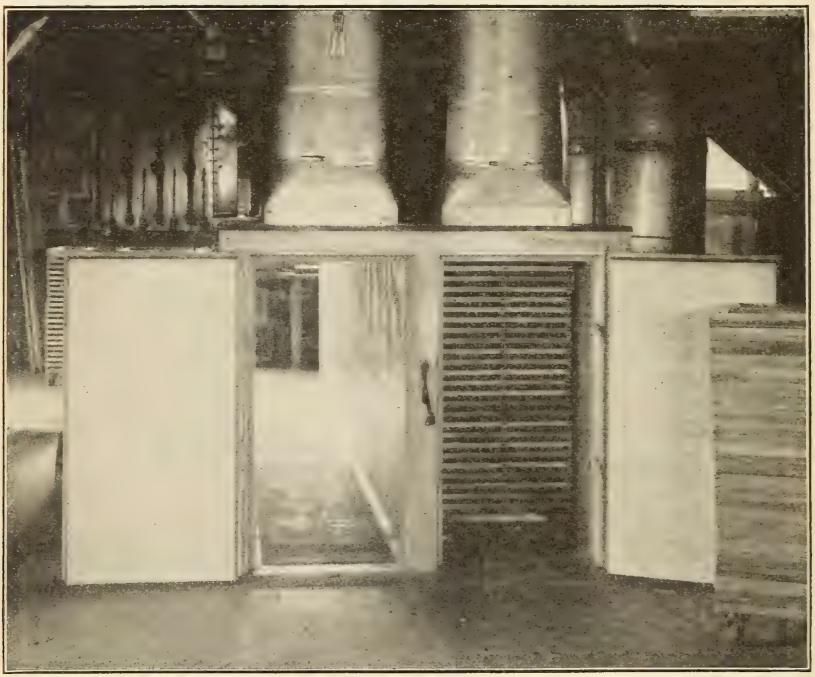

FIG. 2.—Well-constructed double-tunnel drier lined with galvanized iron. Two large pipes take off the heated air after it has passed over the casein. Steam radiator for heating the air shown at top and farther end of tunnel.

with dry sawdust or other insulating material. It is advisable to line the tunnels with galvanized iron if they are to be used continuously, as the large volume of heated air passing through them dries the boards out to a considerable extent. A cheaper type of construction consists in nailing tongue-and-groove boards on only one side of the studding. While, because of leaks and other losses, that kind of drier is not so economical of the heated air, it gives satisfactory results. It is more economical of both space and construction to have a double-tunnel drier built along the wall where it will be least in the way. The tunnel should be made one inch wider than the trucks and drying trays, to allow sufficient room for moving the

stacked trays freely through it. Many tunnels are made 31 or 32 inches wide to accommodate the 30-inch-square drying trays which can be purchased ready-made. The tunnels used in our experiments were 24 inches wide (fig. 2). A double-tunnel drier, 22 feet long, 5 feet high, and each tunnel 24 inches wide, when filled with drying trays will hold the casein from 20,000 pounds of buttermilk. The driers can be made of any length and height but it is advisable to have them high enough to allow a man to walk in without inconvenience when pushing the trays in or out. Full-width doors are placed on each end of the tunnels, so that the trucks stacked full of trays may be pushed in at one end and out at the other, which facilitates and systematizes the work. The cost of a drying tunnel can be ascertained by considering the type of construction and the price of material and labor available in the locality.

BLOWER AND HEATING APPARATUS.

A low-pressure blower of sufficient capacity to provide a large volume of heated air over the ground curd is required. No exact figures as to the cost of a blower can be given. One of the casein jobbers quotes a price of $35 on a blower and $50 for a heater which has sufficient radiating surface to heat the air to the required temperature. The additional expense of installing the apparatus, supposed to have a capacity for drying the casein from 15,000 pounds of milk daily, should also be considered. It may be possible to make a pipe heater at the factory more cheaply than it can be purchased, but if the best results are to be obtained care must be taken to have the proper radiating surface.

DRYING TRAYS AND TRUCKS.

Satisfactory drying trays of the desired size can be made of $\frac{7}{8}$-inch square strips and galvanized screening. A rectangular frame is made of the strips, which are mortised and glued at the corners. Another strip is mortised lengthwise of the frame. Galvanized screening, 16 meshes to the inch, such as is used for windows and doors, is tacked to one side of the frame, after which $\frac{1}{2}$-inch by $\frac{7}{8}$-inch strips are placed over the screen, flush with the lengthwise strip, and fastened with screws. The three strips forming the bottom of the tray allow a free circulation of air through the stacked trays, and in addition materially strengthen it. Canvas or unbleached muslin used on the bottom tray of each truck, in place of the screening, serves to catch the fine particles of dried casein that drop through the upper trays. With galvanized-wire screening at the prices that prevailed in 1914, when the experimental equipment was installed, the 23 by 30 inch trays may be made for $7 a dozen and the 30 by 30 inch trays for about $9 a dozen.

The trucks for holding the drying trays are made of surfaced 2 by 4 inch lumber, or other suitable material, the same size as the trays, and have mortised joints and a swivel caster at each corner. Strong and serviceable trucks can be made complete for $2.50 each. Much cheaper trucks can be made, of course, but it is doubtful whether they would prove to be more economical in the end. The number of trucks and trays needed depends to a large extent upon the time in which the casein is to be dried. Twelve wooden trucks and 30 dozen trays should be available to handle 15,000 pounds of buttermilk daily. By loading them more heavily, more buttermilk can be

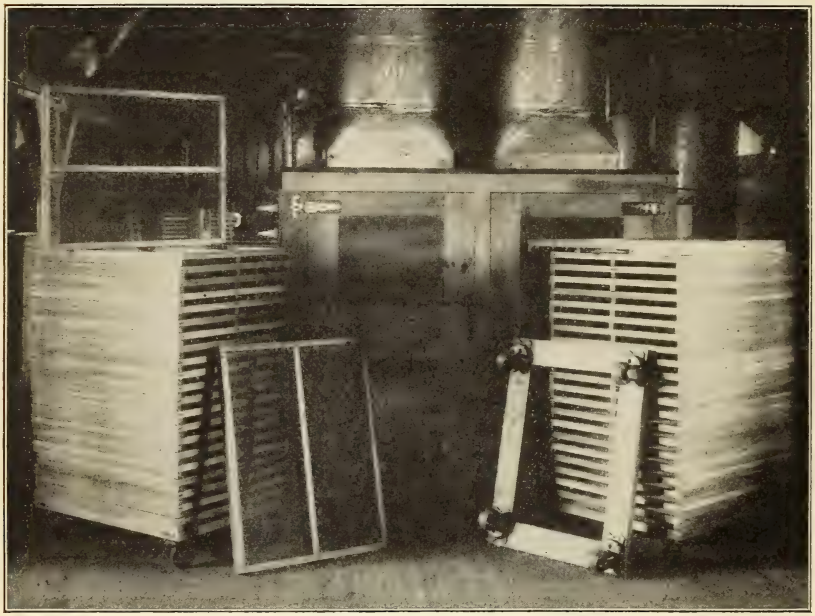

FIG. 3.—Screen-covered drying trays and caster trucks used in drying the ground curd.

handled with the same number of trays, but in this case the time of drying is materially increased.

CURD MILL.

The importance of getting the right kind of curd mill, which is used to grind the green curd taken from the press, can not be overestimated. If the curd is not ground properly the most favorable drying conditions can not be obtained. In order to do satisfactory grinding the mill should have both the shredding and beating features possessed by the better machines (see fig. 4). The shredding part consists of a comparatively slow-revolving cylinder fitted with sharp-peg teeth to tear the large masses of curd into small pieces

that fall into the lower cylindrical drum in which a rapidly revolving iron beater drives the curd through a medium-mesh screen. For the curd of not more than 20,000 pounds of buttermilk a curd mill having both features referred to and one which is suitable for satisfactory work can be purchased for about $50. If more material is to

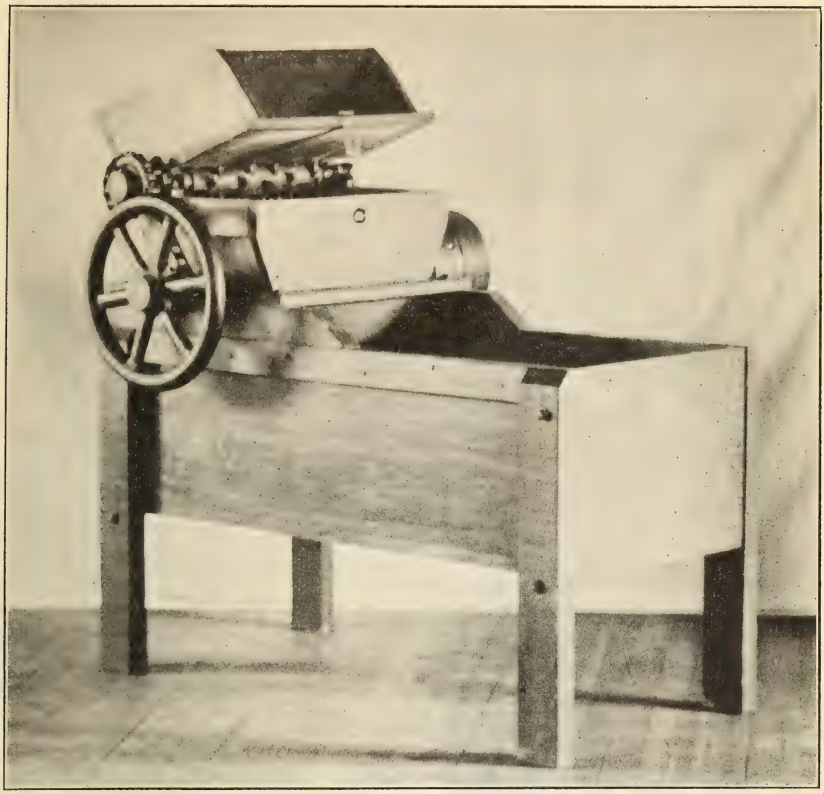

FIG. 4.—An inexpensive but satisfactory type of curd mill, possessing both the shredding and revolving beater features.

be handled regularly it is advisable to purchase a larger, better constructed, and more expensive mill.

CURD PRESS.

The curd press is subjected to a heavy strain and necessarily must be strongly constructed. A sufficiently strong press rack can be made easily of 4 by 4 inch material held together with $\frac{5}{8}$-inch iron bolts. Two pieces of 4 by 4 inch surfaced material 5 feet long and 2 pieces 4 feet long are made into a rectangular form, the 5-foot pieces being fastened to the shorter ones by the use of a $\frac{3}{4}$-inch mortise in such manner as to leave a 30-inch space between the inner edges

of the longer pieces. This allows for a 5-inch projection of each end of the shorter pieces. A 32-inch piece of 4 by 4 inch fitted at the middle into one of the short pieces, so as to form a cross, serves as the floor support. Fourteen-inch pieces of 4 by 4 inch are toenailed to the crosspiece at each end flush with the uprights. On the top of the floor support surfaced boards are nailed. It is advisable to place a shallow pan of galvanized iron on top of the boards for the purpose of diverting the drainage water to one side, thus preventing it from running on to the lower part of the press rack. The uprights of the rack are braced from the opposite sides, the brace running from the outside edge of the floor platform to a point about 30 inches above on the upright. The whole press frame is bolted together with $\frac{5}{8}$-inch bolts which are as long as the uprights, and one is placed parallel with and on the inside of each upright. Heavy iron plates are used for washers on the top and bottom crosspieces. Press jackscrews can be placed in the top crosspiece, which should be of 4 by 6 inch material or with ordinary jackscrews 4 by 4 inch material may be used.

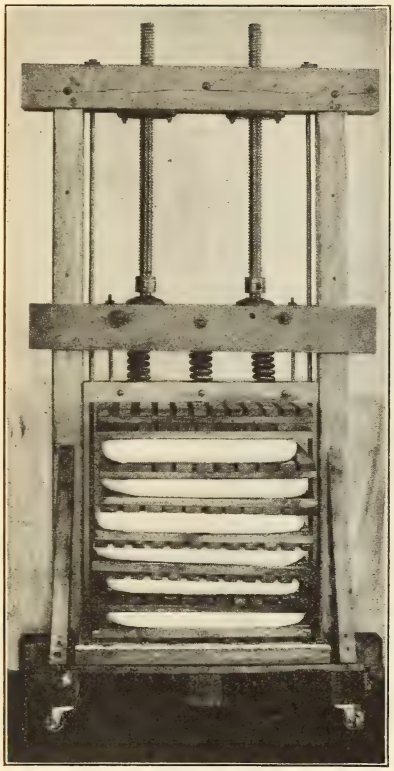

FIG. 5.—Curd press, showing manner of pressing moisture from curd. By means of heavy car springs a continuous heavy pressure may be maintained.

A press of the dimensions given will hold the curd of 5,000 pounds of buttermilk and can be made for about $15, including all labor, material, and two jackscrews. By increasing the cross dimensions a larger press can be made, and it may be advisable to make one wide enough to accommodate a mass of curd 30 inches square. It will be found advantageous to use two jackscrews in each press to facilitate handling the wet curd. The tendency of the moist curd to press unevenly can be better controlled by applying pressure with two jackscrews instead of one. If no one is at the plant to maintain a continuous pressure on the curd in the press, some other means, such as the use of heavy railway-car springs, should be provided to maintain the pressure.

DRAIN RACK.

A drain rack such as is used in the manufacture of cottage cheese is very satisfactory. It should be made either of cypress or of a good grade of white pine. A frame 3 feet 4 inches wide by 6 feet 4 inches long, outside dimensions, is made of surfaced 2 by 4 inch material, using mortised joints and allowing the ends of the longer pieces to project 3 inches. The frame is made by laying the 2 by 4 inch pieces flat. On the inside edge of each piece a $\frac{7}{8}$-inch hole about 2 inches deep is bored every 12 inches, and a $\frac{1}{2}$-inch galvanized pipe of the proper length is placed in the holes when putting the frame together. The pipes support the wire screening and keep it from getting loose. Three galvanized swivel casters are fastened to each side on the bottom of the frame to allow the drain rack to be handled conveniently. Galvanized-wire screening of four meshes to the inch is nailed to the top of the frame with staples, taking care to draw it tight and let it extend a little over the middle of the frame all around. A wooden strip, wide enough to cover the edge of the galvanized screening, is nailed around the outside edge of the upper part of the frame to hold the top part in proper position. The top part is made of $1\frac{1}{2}$ by 12 inch surfaced material with mortised and spiked corner joints, each end of the side pieces projecting 6 inches. The projections, trimmed down to the shape of a handle, make the rack more convenient.

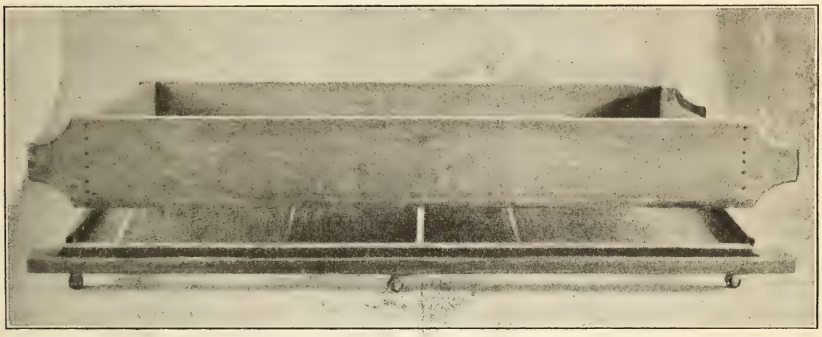

FIG. 6.—Drain rack mounted on swivel casters allows most convenient handling, especially when filled with curd.

Two drain racks of the dimensions given are large enough to hold the curd from 400 gallons of buttermilk. The curd drains quickly in the drain racks, which permits them to be used repeatedly until all the casein is made.

PRESS FORM-DIVIDING BOARDS.

The dividing boards placed between the layers of wet curd in the press can be made conveniently from 1 by $1\frac{1}{2}$ inch lattice-stop strips

surfaced on all sides. The strips are cut in 26-inch lengths and nailed crosswise to one another, allowing 1 inch between strips; the dividing board is then 26 inches square and is suitable for the press described. A smaller space than 1 inch between the strips makes washing difficult, while a much larger one allows the curd to project, which causes unsatisfactory pressing. For making the dividing boards use good clear wood which can be washed easily. It is advisable also to give all form-dividing boards at least two coats of raw linseed oil before using, to reduce the water-retaining capacity of the wood. The boards are kept wet while in use and unless oiled well

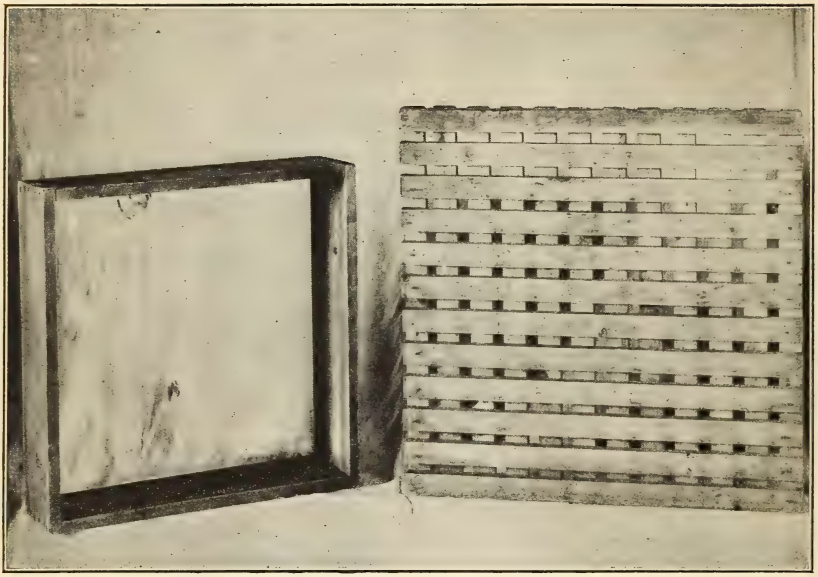

FIG. 7.—Dividing board and form used in putting the curd into the press cloths.

will soon become heavy with moisture. They must be scrubbed well each day with hot water and a brush, to prevent offensive odors. When lattice-stop strips cost 1.3 cents a linear foot, allowing for carpenter's time, the dividing boards of the size indicated can be made for about 95 cents each.

DRAIN AND PRESS CLOTHS.

Experience with several kinds of cloth, both for draining and pressing the curd, has shown that certain kinds of material are to be preferred. The drain cloth must be strong to prevent tearing in manipulating the heavy wet curd, must allow easy drainage, and must be easy to wash. Ordinary burlap makes a strong, serviceable drain cloth which no doubt will outlast any other material. Cheese-

cloth is not strong enough to make a satisfactory drain cloth. Two pieces of 36-inch burlap three yards long, sewed together at the middle with a treble seam, make a drain cloth of suitable size for a drain rack 3 feet wide, 6 feet long, and 12 inches deep. The edge of the cloth should be hemmed to prevent raveling and unnecessary wear.

For pressing the wet curd 10-ounce duck seems to be most satisfactory, since it has the greatest strength, is easy to wash, and does not allow the curd to escape. Burlap of a very close weave can be used, but is much harder to wash. Unbleached muslin is satisfactory but does not equal the duck. Any of the materials mentioned can be obtained in widths suitable for making cloths of the proper size to use with the curd press and dividing boards described. Pieces 41 inches long, cut from a 40-inch bolt, after the torn edge has been hemmed to prevent raveling, make cloths of suitable size for a form 20 inches square and 8 inches deep.

FACTORS INFLUENCING THE QUALITY OF BUTTERMILK CASEIN.

The difference and variation in chemical composition and physical condition of buttermilk make it hard to control absolutely all conditions which may influence the quality of the casein. In making the different lots of buttermilk casein conditions were controlled so far as was practicable, so that the factor studied was the only variable introduced. That makes it possible to observe, on a fair and comparative basis, the effect of any factor under consideration.

The factors that have an important influence upon the quality of the buttermilk casein are:

Fat content of buttermilk.
Washing the precipitated curd.
Temperature of drying the ground curd.
Temperature of precipitating the curd.
Acidity of buttermilk at the time of precipitation.

FAT CONTENT OF BUTTERMILK.

Since all the fat originally in the buttermilk is concentrated in the dried casein it probably will have a deleterious effect upon the strength and general working properties of the casein. An increased quantity of fat yields not only a casein of poorer solubility and strength, but also a solution of poorer physical qualities. A lot of buttermilk was divided into two parts and fat in the form of cream added to one part, which was used as a basis for observing the effect of increased fat content upon the quality of the casein.

TABLE 1.—*Effect of fat content of buttermilk on strength of casein.*

Buttermilk.			Times curd washed.	Acidity of drain water.	Drying temperature.	Fat in buttermilk.	Casein required.
Lot No.	Portion No.	Acidity.					
		Per cent.		*Per cent.*	*° F.*	*Per cent.*	*Grams.*
56.17	17A	0.95	4	0.035	130	1.2	12
56.17	17B	1.00	3	.20	130	.07	10
56.30	30A	.85	4	.015	130	.02	9
56.30	30B	.88	4	.015	130	.30	10
56.53	53D	.67	4	.09	125	.05	9
56.53	53D	.70	4	.07	125	.50	10
56.53	53A	.67	4	.10	165	.05	9
56.53	53C	.70	4	.06	165	.50	11
56.55	55A	.82	4	.02	125	.07	8
56.55	55C	.82	4	.01	125	.32	9+
56.55	55B	.83	4	.02	160	.07	8
56.55	55D	.83	4	.01	160	.32	9
56.58	58A	.87	4	.02	125	.06	9
56.58	58B	.86	4	.02	125	.27	9
56.62	62A	.80	4	.015	125	.04	7
56.62	62B	.80	4	.02	125	.35	8
56.64	64A	.....	4	.03	125	.11	7+
56.64	64B	.....	4	.03	125	.28	7
56.64	64C	.....	4	.04	160	.11	8
56.64	64D	.....	4	.03	160	.28	8
56.71	71A	.....	4	.06	125	.08	8+
56.71	71C	.....	4	.07	125	.30	9
56.71	71B	.....	4	.10	175	.08	8
56.71	71D	.....	4	.07	175	.30	9
56.72	72A	.....	4	.04	125	.08	7
56.72	72C	.....	4	.05	125	.30	8+
56.73	73A	.....	4	.02	125	.20	8+
56.73	73C	.....	4	.00	125	.80	9+
56.73	73B	.....	4	.02	168	.20	9
56.73	73D	.....	4	.01	168	.80	10
56.74	74A	.....	4	.01	125	.2	7+
56.74	74C	.....	4	.02	125	.8	9−
56.84	84A	.....	0	.46	126	.17	8
56.84	84C	.....	0	.38	126	.50	10
56.84	84B	.....	0	.37	162	.17	8
56.84	84D	.....	0	.40	162	.50	10+
56.87	87A	.....	3	.05	126	.28	8−
56.87	87C	.....	3	.03	126	.83	9−
56.87	87B	.....	0	.48	126	.28	8+
56.87	87D	.....	0	.41	126	.75	9

Table 1 shows the comparative strength of different lots in terms of grams of casein required to hold the coating mixture properly. If it is assumed that the difference in strength is caused entirely by the extra fat content we find that in lot 56.17 the low-fat buttermilk casein was 20 per cent stronger than the higher-fat buttermilk, while in lot 56.30 the difference in strength in favor of the low-fat buttermilk casein was 11 per cent. The greater strength shown by the low-fat buttermilk casein in practically all instances is more significant when it is considered that the high-fat buttermilk casein showed decreased strength together with poorer handling qualities. The increased quantity of fat has a detrimental effect upon the physical working qualities of the dissolved casein, producing a thin, weak-bodied solution of greatly reduced viscosity which upon cooling has a tendency to become a greasy mixture of poor spreading qualities.

Having in view trying out the effect of increased fat content with a high drying temperature as compared with a low temperature, lots

of low-fat buttermilk were divided into two portions and cream added to the one to make it high in fat. The low-fat and high-fat portions were then subdivided into two portions. All portions were run as nearly alike as possible until time of drying, when one low-fat and one high-fat portion were dried at normal temperature, and the other set of low-fat and high-fat portions were dried at a temperature far in excess of that recommended for the best results. This gives a combination of factors which makes it difficult to judge the deleterious effect of the fat content upon the quality of casein. Lots numbered 56.64, 56.71, and 56.73, Table 1, involving the two influencing factors, do not show so much difference in strength with the high fat and high drying temperature as may be expected. It must be understood, though, that the wax test is by no means a sensitive one, merely giving rough comparative results, and for that reason can not be relied upon to measure accurately the actual relative strength of given samples of casein. This point should be borne in mind in considering the data and discussion relating to the effect of the various factors upon the strength of the casein samples reported upon in this work. In Lot No. 56.84 three influencing factors are introduced—washing, drying temperature, and fat content—and the difference in strength of these samples is very pronounced. The difference in strength in this set of samples can not be attributed altogether to the fat content, for the lack of washing the curd and the higher drying temperature have a probable influence which must be given due consideration.

WASHING THE CURD.

Contrary to a current opinion existing among casein firms, particularly with reference to skim-milk casein, the investigational work indicates that the washing of the buttermilk curd is of importance. Washing removes the free whey and with it lactose and soluble salts which may serve as impurities in the casein. While the effect of the salts which may be removed by washing has not been definitely determined, it is reasonable to conclude that the presence of an excess of lactic acid adds complications and in that way favors a deterioration in quality, since the washed-curd casein from high-acid buttermilk shows greater strength. Soluble salts retained in the curd in their natural form probably do not have a direct effect upon the quality of casein, but their presence, in connection with other factors such as high fat content and high drying temperature, may injure the quality. The ash content of the casein indicates to a certain extent the salts present, and while it serves as a guide in judging whether the curd has been washed it can not be depended upon as a reliable indicator of the quality of the casein.

TABLE 2.—*The effect of washing curd on the strength of the casein.*

Buttermilk.			Butter-milk fat content.	Times curd washed.	Acidity of drain water.	Drying temper-ature.	Casein required.	Ash.	Fat.	H_2O.
Lot No.	Portion No.	Acidity.								
		Per cent.	*Per cent.*		*Per cent.*	*° F.*	*Grams.*	*Per cent.*	*Per cent.*	*Per cent.*
56. 9	9A	0. 82	0. 20	0	0. 60	125	12	1. 65	23. 32	5. 84
56. 9	9B	. 82	. 20	4	. 04	125	10	0. 26	22. 55	5. 33
56. 10	10A	. 72	. 16	2	. 19	125	9	1. 18	5. 86	7. 14
56. 10	10B	. 72	. 16	4	. 05	125	9	0. 88	6. 04	7. 65
56. 20	20A	. 81	. 01	0	. 54	125	9	2. 18	4. 29	5. 91
56. 20	20B	. 81	. 01	4	. 14	125	9	1. 26	4. 07	5. 68
56. 31	31A	. 81	. 12	0	. 58	125	9	.....	.....	.....
56. 31	31B	. 81	. 12	4	. 05	125	8	.....	.....	.....
56. 35	35A	. 65	. 19	0	. 44	125	9	2. 38	4. 18	5. 90
56. 35	35B	. 65	. 19	5	. 07	125	9	0. 86	4. 66	6. 14
56. 50	50A	. 67	. 06	0	. 42	125	8	.....	.....	.....
56. 50	50B	. 67	. 06	2	. 14	125	8	.....	.....	.....
56. 52	52A	. 74	. 32	0	. 42	125	9	.....	.....	.....
56. 52	52B	. 76	. 32	4	. 04	125	8 +	.....	.....	.....
56. 52	52C	. 97	. 32	0	. 57	125	10	.....	.....	.....
56. 52	52D	. 96	. 32	4	. 02	125	9	.....	.....	.....
56. 54	54AC	. 63	. 07	4	. 04	125	9	.....	.....	.....
56. 54	54BD	. 63	. 07	0	. 37	125	9 +	.....	.....	.....
56. 56	56A	. 93	. 14	0	. 56	125	10	.....	.....	.....
56. 56	56B	. 93	. 14	4	. 02	125	8 +	.....	.....	.....

Table 2 gives data on the effect of washing the curd upon the strength of the casein. The increased strength consistently shown in the washed curd from high-acid buttermilk emphasizes the importance of washing the curd from that kind of material. No noticeable increase in strength could be found, however, in the washed curd of low-acid buttermilk. Any difference in strength appears more marked in the samples made from buttermilk of higher acidity or fat content, substantiating the assumption that it was caused by a combination of factors which by themselves may not have any direct effect. The samples from the unwashed curd, taken as a whole, required more time to effect a complete solution, which may have been caused by the free acid remaining in the whey rather than by any injury to the quality of the casein. A portion of the alkali is used up in neutralizing the free acid found in the unwashed-curd casein, thus leaving a weaker solution for dissolving the sample. The reaction accounts for the decreased quantity of alkali found necessary to dissolve the casein from a well-washed curd.

DRYING TEMPERATURE OF THE CURD.

A high drying temperature in combination with one of the other factors has an injurious effect upon the quality of the casein which is most pronounced with a high-fat or unwashed curd. A well-washed curd from buttermilk of a low-fat content can be dried at a relatively high temperature with no apparent injury to the quality, but it is not to be recommended. The lower the temperature the less probability of injuring the quality, and for that reason the lowest temperature possible should be used. A temperature of 130° F.

(54.44° C.) is satisfactory for quick drying and should have no injurious effect upon the quality of the casein.

TABLE 3.—*Effect of drying temperature on strength of casein.*

Buttermilk.		Times curd washed.	Acidity of drain water.	Fat in buttermilk.	Drying temperature.	Casein required.
Lot No.	Portion No.					
			Per cent.	*Per cent.*	° *F.*	*Grams.*
56.15	15A	4	0.07	0.35	125	9
56.15	15B	4	.07	.35	150	9
56.16	16A	4	.02	.60	130	8
56.16	16B	4	.02	.60	160	9
56.20	20B	4	.14	.01	125	9
56.20	20C	4	.14	.01	93	9
56.23	23A	4	.005	.13	130	9
56.23	23B	4	.005	.13	160	9+
56.53	53A	4	.10	.05	165	9
56.53	53B	4	.09	.05	125	9
56.53	53C	4	.06	.50	165	11
56.53	53D	4	.07	.50	125	10
56.55	55A	4	.02	.07	125	8
56.55	55B	4	.02	.07	160	8
56.64	64A	4	.03	.11	125	7+
56.64	64C	4	.04	.11	160	8
56.64	64B	4	.03	.28	125	7
56.64	64D	4	.03	.28	160	8
56.71	71A	4	.06	.08	125	8+
56.71	71B	4	.10	.08	175	8
56.71	71C	4	.07	.30	125	9
56.71	71D	4	.07	.30	175	9
56.73	73A	4	.02	.20	125	8+
56.73	73B	4	.02	.20	168	9
56.73	73C	4	.00	.80	125	9+
56.73	73D	4	.01	.80	168	10

Table 3 shows the effect of the drying temperature upon the strength of the casein. There are no apparent differences in strength from low-fat buttermilk; but with the higher-fat buttermilk a difference in strength, attributable to the higher-drying temperature, is noted. No apparent differences in strength show up consistently with the low-fat buttermilk due to the high drying temperature. While the differences in strength of the high-fat portions of buttermilk in Lots 56.53, 56.64, 56.71, and 56.73 do not show up so markedly as would be expected, they nevertheless indicate clearly the weakening effect which a high drying temperature has upon the quality of casein from buttermilk high in fat.

PRECIPITATING TEMPERATURE.

The temperature of precipitating the curd is not of great importance, as the range of heat which may be used in obtaining a rapid and clear separation of curd from whey does not permit a temperature high enough materially to affect the quality of the casein. Precipitation of the curd is accomplished within certain limits which, if exceeded, will fail to give the characteristic separation desired. A high precipitating temperature, particularly with buttermilk of high acidity, causes the mixture to reemulsify, thus

preventing separation. The precipitating temperature, under normal conditions, is largely controlled by the process itself and ordinarily is not high enough to cause material injury to the quality of the casein.

ACIDITY OF BUTTERMILK.

The acidity of buttermilk at the time of precipitation is of importance only when the curd is not well washed, the effect of which is discussed under "Washing the curd." When high-acid buttermilk curd is well washed no appreciable difference in the strength of the casein can be distinguished. High-acid buttermilk is more liable to give trouble in handling and so should be avoided whenever it is possible.

THE MANUFACTURE OF SKIM-MILK CASEIN.

SULPHURIC-ACID METHOD.

The usual method of making skim-milk casein is that of adding crude commercial sulphuric acid to the fresh skim milk after heating the latter to a temperature of 120° F. (48.89° C.). The advantage of this method is that the skim milk can be disposed of quickly and at a time when the quality of the curd is in the best condition.

The fresh skim milk is run into a vat, generally of wood because of its cheapness and the deteriorating effect of acid upon a metal vat. It is there heated with direct steam to a temperature of 120° F. (48.89° C.) and never higher than 125° F. (51.67° C.). Commercial sulphuric acid, of the strength used for making Babcock tests (1.83 specific gravity), is then added at the rate of one pint to every 1,000 pounds of milk, at the same time stirring the mixture continuously. Before using, each pint of acid should be diluted with about a gallon of water, always pouring the acid into the water and not vice versa. After the addition of the acid the skim milk is stirred gently until a good separation of the curd is obtained, as indicated by the clearness of the whey. This usually takes but a few minutes, provided sufficient acid has been used. In case the curd does not separate well, leaving a clear whey, more acid can be added to get the proper results. The quantity of acid required for a good, clear separation varies somewhat, depending upon its strength and the condition of the milk. The proper quantity can be determined easily if the vat is marked off so as to show how much milk is on hand for each run. By varying the quantity of acid used from day to day the proportion that gives the best results can be ascertained. The clear whey is run through the gate valve at once, and the curd remaining in the vat is rinsed with cold water to remove the excess of whey and the free acid remaining. When the curd in the vat has drained it is placed in

burlap press cloths and put to press. While burlap is generally used for pressing the skim-milk curd it is not so satisfactory as duck, since the curd adheres to it more and makes washing more difficult. Continuous heavy pressure is applied until sufficient whey has been expelled to permit satisfactory grinding. The time required depends upon the degree of pressure and the condition of the curd. The usual practice is to allow the curd to remain in the press over night. After it has been pressed properly the curd is taken from the press and, after being run through the curd mill, the ground curd is placed upon the trays and dried in the tunnel drier.

PRESSED-CURD METHOD.

Creameries without a sufficient quantity of skim milk to justify the expense of installing a complete plant for manufacturing the dried casein may ship the pressed curd to a central drying plant, several of which are maintained by casein jobbers in creamery districts. At the central drying plant the green-pressed curd is ground, dried, and paid for on the basis of dried casein obtained. When the pressed curd is shipped the only equipment required besides the vat is the press, press cloths, and dividing boards, none of which are expensive.

The green curd has to be shipped frequently during the warm weather, unless it can be kept in a refrigerator, and must remain in transit only a very short time. The green-pressed curd soon begins to mold, which has an injurious effect upon the quality of the casein.

COOKED-CURD METHOD.

The cooked-curd method of making skim-milk casein is coming into more general use among the creameries in districts convenient to a central drying plant. This method requires practically no equipment except the precipitating vat. The process of precipitating is the same as that used for pressed curd; that is, the skim milk is heated to 120° F. (48.89° C.) and sulphuric acid added at the rate required to separate properly. After draining the whey off the curd is broken up in the vat, covered with water, and the mixture heated to a temperature of 170° to 175° F. (76.67° to 79.44° C.) by means of direct steam. At that temperature all the curd should collect in a semifluid, plastic, tough mass. The water is drained off and the soft curd placed in a barrel, where it settles into an almost air-tight mass which upon cooling changes to a very tough, impervious mass that will keep for several days, even in hot weather. Fresh-cooked curd can be put on top of the hardened curd in a barrel partially filled from a previous batch. The barrels filled with cooked curd and covered with burlap can be shipped to the central drying plant without danger of breaking. Cooked curd is very hard to grind and requires an especially strong mill.

No more acid than is required to give a clear separation should be used, as an excess seriously interferes with the proper working of the cooked-curd method. When too much acid is added, the curd, when cooked in the water, does not collect in the characteristic plastic mass but breaks up fine, making it difficult to handle. When the proper quantity of acid has been used in precipitating the curd, the clear whey shows an acidity of from 0.30 to 0.32 per cent. If it shows more than 0.34 per cent acidity, trouble is liable to be encountered in obtaining the characteristic fusion of the curd at the

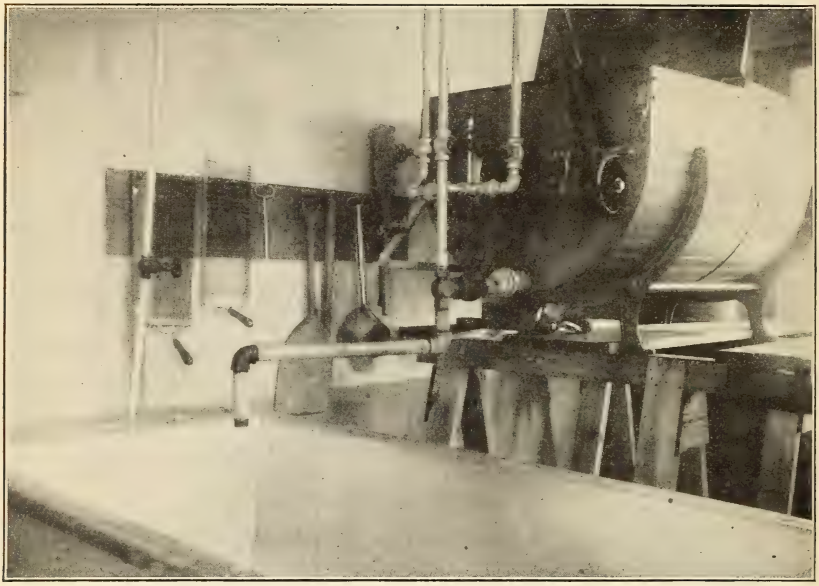

FIG. 8.—Connecting the ejector to a tank elevated sufficiently to allow heated buttermilk to be run into a vat below gives satisfactory working conditions.

time of heating. A good plan to follow in preventing the use of an excess of acid is to measure out what the directions call for—one pint to a 1,000 pounds of skim milk—dilute all of it with water, and then add a portion at a time, using just what is necessary to effect a clear and complete separation.

EJECTOR METHOD.

Casein can be made successfully from skim milk with the ejector method of precipitating the curd, but care must be taken in allowing the skim milk to curdle before heating, or a tough, rubbery curd, impossible to handle, will result. When skim milk is allowed to curdle by the formation of lactic acid and without agitation, then there is no trouble in getting a clear and quick separation of the curd which can be handled well in every respect. The curd from naturally soured skim milk, separated by the ejector method of heating, is not

only handled as easily as that precipitated with sulphuric acid but is not nearly so tough nor so hard to grind.

COMPARISON OF THE DIFFERENT METHODS OF MAKING SKIM-MILK CASEIN.

The quality of casein made by the ejector method is superior in many ways to that made with the acid and cooked-curd methods. It shows better strength, dissolves more readily, and retains a fluid, viscous body at room temperature, giving it better working properties. When dissolving acid and cooked-curd casein, complete solution is retarded by the formation of a heavy, short, viscous body, which upon cooling has a decided tendency to congeal and lose its fluidity, more especially the cooked-curd casein, making it very difficult to mix well with other solutions in the cold. Table 4 shows the comparative strength of casein made from the same lots of skim milk with the ejector, acid, and cooked-curd methods.

TABLE 4.—*Comparative strength of skim-milk casein made with ejector, acid, and cooked-curd methods.*

Skim milk.		Times curd washed.	Acidity of drain water.	Drying temperature.	Method.	Casein required.
Lot No.	Portion No.					
			Per cent.	° *F.*		*Grams.*
56.25	25A	1	0.38	130	Sulphuric acid.	9
56.25	25B	4	.10	130	Ejector	8+
56.33	33A	1	.22	130	Sulphuric acid.	9
56.33	33B	4	.00	130	Ejector	8
56.34	34A	1	.14	130	Sulphuric acid.	8
56.34	34B	4	.02	130	Ejector	8
56.59	59A	0		130	Sulphuric acid.	10
56.59	59B	0		130	Cooked curd	9+
56.59	59C	3	.01	130	Ejector	8
56.60	60A	0	.28	128	Cooked curd	9
56.60	60B	0		128	Sulphuric acid.	9
56.60	60C	3		128	Ejector	8
56.61	61A	0	.53	130	Sulphuric acid.	9
56.61	61C	0	.25	130	Cooked curd	9+
56.61	61D	3	.06	130	Ejector	8
56.89	89A	1	.13	124	Sulphuric acid.	8
56.89	89B	1	.10	124	Cooked curd	9
56.89	89C	3	.09	124	Ejector	7+
56.90	90A	3	.04	124	Sulphuric acid.	8
56.90	90B	1	.06	124	Cooked curd	9
56.90	90C	3		124	Ejector	7+

In seven out of eight experiments the wax test showed the ejector-method casein to be the strongest, while in one lot no difference was noticeable. While the difference in strength is not marked in all cases, it shows up with such consistency as to warrant fully the conclusion that the ejector casein is stronger when made under proper conditions. The increased strength of the ejector-method skim-milk casein and its much better working properties make it the most desirable from the standpoint of quality. The ejector method requires more vat capacity, as the skim milk has to be held until it has developed a sufficient degree of acidity to bring about a firm coagu-

lation. The acid and cooked-curd methods have the advantage of requiring less vat capacity, and the casein can be made up in a shorter time.

YIELD OF SKIM-MILK CASEIN.

The yield of skim-milk casein will vary from 2.9 to 3.5 per cent, depending upon the composition of the skim milk, the method of manufacture, and the extent of drying. Because of the better physical condition of the skim-milk curd there is not so much occasion for loss of curd as in the case of buttermilk, and the yield is there-

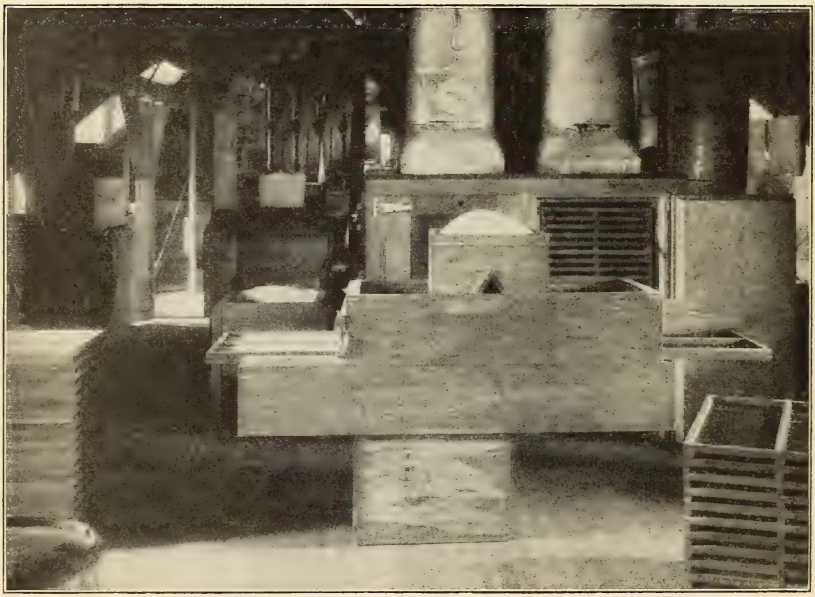

FIG. 9.—By means of a simple shaker screen the ground curd can be spread on the trays in a short time and in a manner giving the most favorable drying conditions.

fore higher. When the skim-milk casein is dried well, so that it does not contain more than from 5 to 7 per cent of moisture, the yield, with skim milk of average composition, ranges between 3 and 3.25 pounds to 100 pounds of skim milk.

REQUIREMENTS FOR GOOD CASEIN.

The practical value of casein depends upon its solubility, adhesiveness, and general working properties. Casein of the desired quality should dissolve within certain limits of alkalinity, giving a clear, uniform solution, free from any scum or sediment, have a fairly heavy body, and possess good adhesive qualities. The general working properties of the dissolved casein, as determined by its vis-

cosity and spreading qualities, must be satisfactory. Any factor that has an influence upon any of the requirements for making a good grade of casein necessarily affects the quality of the product.

The physical condition and chemical composition of skim milk favors the making of a high-grade casein and, provided proper attention is given to the details of manufacture, little difficulty is encountered in making a good grade.

The manufacture of casein from buttermilk, however, presents an entirely different proposition, because of the differences in chemical composition and physical condition of the latter and consequently the increased number of factors which have a direct or indirect influence upon the quality of the casein. The wide variation shown in the quality of buttermilk casein made in the ordinary way indicates clearly the presence of factors influencing its manufacture and having a direct effect upon the quality. A comparison of chemical analysis of normal samples of skim milk and buttermilk shows a higher percentage of fat and lactic acid in the buttermilk, with a decrease in the percentage of lactose equivalent to the increase of lactic acid brought about by fermentation. As fat is undesirable in casein, it is natural to suppose that the increased quantity found in buttermilk would have a marked influence in injuring the quality of the casein. While the difference in fat content may not appear to be so marked in the raw buttermilk, its effect upon the final product will be readily understood when it is considered that the fat in the dried casein is about 33 times that shown by the Babcock butterfat test. The practical creamery method of determining the fat content of buttermilk can not, of course, be regarded as highly accurate, and in consequence it does not always indicate correctly what the fat content of the dried casein will be. In nearly all instances in which buttermilk of a normal fat content was used, the finished casein contained a much higher concentration than the Babcock test of the buttermilk indicated should be present. Table 5 shows the theoretical fat content of the dried casein, based upon the Babcock test for fat in buttermilk and calculated on the basis of the yield in pounds per hundred pounds of buttermilk, compared with the actual fat content of the dried casein as determined by the ether-extraction laboratory method. The figures as a whole do not represent lots of casein made under conditions found requisite to the manufacture of a high-quality product and should not be taken as representative of the analysis of properly made buttermilk casein.

While the increased quantity of lactic acid found in buttermilk may not have in itself any appreciable effect upon the quality of the casein, its presence in combination with one or more of the other influencing factors is very liable to be of considerable importance.

TABLE 5.—*Comparison of calculated and actual fat content of casein.*

Sample No.	Fat content of buttermilk.	Fat content of casein.	
		Calculated.	By ether extraction.
	Per cent.	*Per cent.*	*Per cent.*
56.3	.07	2.31	6.36
56.4	.18	5.94	9.89
56.9B	.20	6.60	23.83
56.10A	.16	5.28	6.31
56.12A	.28	9.24	8.71
56.13A	.89	29.37	21.27
56.14	.015	.495	.93
56.15A	.35	11.55	12.63
56.16B	.60	19.80	14.40
56.17B	.07	2.31	9.67
56.20A	.01	.33	4.29
56.23A	.13	4.29	9.52
56.25A	.04	1.32	3.98
56.30A	.02	.66	7.53
56.35A	.19	6.27	4.18

All analyses of casein samples were made by R. H. Shaw and E. F. Deysher, of the Dairy Division.

Analyses of samples of domestic and foreign skim-milk casein and of buttermilk casein appear in Table 6 and show the difference in chemical composition. The buttermilk samples, made from what would be regarded as the usual run of buttermilk in creameries receiving a good grade of cream, show a marked increase in fat, as was to be expected.

TABLE 6.—*Comparative analyses of skim-milk and buttermilk casein.*

Sample No.	Origin.	Chemical analysis.		
		Moisture.	Fat.	Ash.
		Per cent.	*Per cent.*	*Per cent.*
56.40	Domestic skim milk	7.80	0.60	2.80
56.41	do	8.28	0.93	2.44
56.43	Foreign skim milk	7.95	0.66	1.89
56.44	Domestic skim milk	6.44	1.04	3.69
56.45	French skim milk	8.43	0.75	1.86
56.14	Domestic skim milk	7.74	0.93	1.14
56.10B	Buttermilk	7.65	6.54	0.99
56.22	do	6.68	5.00	1.30
56.23A	do	6.82	9.52	0.60
56.35C	do	5.86	5.62	.0.76
56.37	do	6.42	5.82	1.19

METHODS OF DETERMINING QUALITY OF CASEIN.

In order to determine factors having a direct bearing upon the quality of buttermilk casein and the conditions requisite to the manufacture of a product of the best practical value, a study of the solubility, adhesiveness, and general working properties of various lots of casein made under varying conditions was undertaken. Buttermilk from pasteurized sweet cream ripened to an acidity of from 0.40 to 0.65 per cent was used in the investigational work, and no

trouble need be experienced in handling that kind of material. The combination of acid in sour cream with the temperature required for pasteurizing has an injurious effect upon the normal handling of the resulting buttermilk. The degree of acidity which may be present in the cream at the time of pasteurization without seriously interfering with the normal working of the buttermilk curd for making casein has not been determined. As a large proportion of the casein of the best quality is used for coating paper, the numerous lots of casein made were tested with special reference to their adaptability and practical value for that industry. The tests applied in the paper industry, however, give results applicable in determining the value of casein for other purposes for which it may be used. The requirements of casein for high-class paper-coating work are rather severe, and lots not suitable for that work often can be used satisfactorily for other purposes.

The casein is used for the purpose of fixing the coating material to the paper in such manner as to make it a part of the paper. In case an insufficient quantity of casein is used the coating ingredients pull away from the paper when put to the test. By using more casein the coating material is held firmly to the paper, which serves as a practical means of determining the strength of the casein. The strength or adhesiveness of all the samples made was ascertained by a laboratory method used by the paper concerns, in which the quantity of casein required to hold the coating mixture properly is determined.

In addition to the tests made in the laboratory large samples of buttermilk casein were sent to two paper manufacturers for the purpose of having commercial coating tests run on their large machines and in that manner determine its practical value and handling qualities. While the results obtained in the large coating machines did not always indicate the effect of the factor under observation in so marked a degree as was found in the laboratory method, they did demonstrate fully that a good grade of casein suitable for high-class coating and lithographing work can be made from buttermilk.

The strength test was used almost entirely in these experiments as a basis for drawing conclusions as to comparative values of casein in studying the effect of the factor under consideration, as there was no trouble in obtaining a complete solution of the casein after adopting a suitable method. The time required for the casein to dissolve is of importance, but slow dissolving does not necessarily indicate a poor grade, as the rate of dissolving may be influenced by factors that have no effect upon the strength. While the casein must dissolve within a reasonable time, its practical value is determined in the final outcome largely by its strength or ability to hold the coating material.

While the test used in determining the strength of the casein can not be regarded as highly accurate from a scientific standpoint, it is more or less valuable in determining in a practical manner the relative value of different samples of casein. The general handling quality of the different lots of casein was observed during the process of dissolving and also during the actual coating work. Difficulties encountered with the solubility or working properties of the samples, caused by any factor introduced to study its effect upon the quality, will be discussed later under the heading of the particular factor.

ADHESIVE OR STRENGTH TEST.

Fifty grams of casein ground fine enough to pass through a screen with 20 meshes to the inch is weighed into a casserole whose weight is known, 100 cubic centimeters of cold distilled water is added, the two mixed well and allowed to stand for a short time, when 90 cubic centimeters more of distilled water is added in which 5 grams of borax has been dissolved. Distilled water is then added until the mixture weighs 250 grams, and the casserole placed in a water bath having a temperature not to exceed 149° F. (65° C.) and stirred until the casein is dissolved. When the casein is completely dissolved more water must be added to take the place of that lost by evaporation, so that each 5 grams of the solution will represent one of casein. Some samples of casein may require more than the specified quantity of borax or other alkali. No trouble was experienced in dissolving the samples reported in the proportion of borax given.

One hundred grams of china clay or kaolin, previously dried at the temperature of boiling water for one hour, is weighed into a heavy casserole, and 70 cubic centimeters of distilled water added and mixed to a smooth paste, care being taken to work up any lumps that may settle to the bottom. After weighing the casserole with its contents of clay paste, 30 grams of the casein solution, representing 6 grams of casein, is added to it and thoroughly mixed with the paste. A stiff brush is helpful in getting a good mixture. A thin coating of the mixture is then applied to several small sheets of test paper by means of a thin brass scraper or camel's-hair brush, using care to spread uniformly. The casserole is again balanced and 5 additional grams of the casein solution added, the solution well mixed and another set of test sheets coated, continuing the procedure of adding 5 grams of the casein solution and making a set of test sheets until sufficient casein has been added to hold the coating mixture properly to the paper. Best results were obtained by using the brass scraper, which requires that the paper be placed on a perfectly flat surface, such as a piece of smooth plate glass. When using a brush the coating mixture should be painted on very quickly, first lengthwise and then crosswise.

When the sets of test papers having an increase of one gram in casein for each succeeding set are perfectly dry, a short stick of sealing wax softened by heating at one end is applied with a fairly firm pressure to various points where the coating is uniform, and allowed to cool. The paper is then held down firmly by placing the fingers on each side of the wax and the latter pulled away with a steady pull. In case of an insufficient quantity of casein the wax will pull only the clay mixture, but when sufficient casein has been used it will pull the paper fibers strongly to the edge of the wax, showing that the coating material had actually become a part of the paper. Usually a transition point is found when the center of the stick of wax will pull the paper fibers partially, while the next set having 1 gram more of casein will pull all the fibers to the extreme edge of the wax. A good grade of casein should not require more than 8 or 9 grams to hold strongly.

The strength of the casein as shown by this laboratory test bears some direct relation to the quantity of casein necessary to use in the practical coating work, and for that reason was used in determining the influence of the various factors observed upon the strength of the casein.

SOLUBILITY TESTS.

Weigh out 50 grams of air-dried sample ground to pass through a 20-mesh screen, add 300 cubic centimeters of distilled water in which 7.5 grams of commercial borax has been dissolved. Heat in a beaker or other flask in a water bath having a temperature not to exceed 149° F. (65° C.). Complete solution should result within 10 minutes. 149½ F. (65° C.). Complete solution should result within 10 minutes with continuous stirring.

CASEIN MARKETS AND PRICES.

The market for skim-milk casein, which is the only kind that has been made in large quantities in the past, has always been good at the prevailing prices. A few years ago the price received for it was from 5 to 7 cents a pound, but during the last two years, owing to the falling off in the importation, the price has doubled or trebled. At one time the exceptionally high price of 22 cents a pound was offered, with very little available. This price was exceptional, of course, and did not prevail for a great length of time. The demand during the last two years has been steady despite the exceedingly high prices. While the market will readjust itself with a resumption of normal conditions the price, in all probability, will not go back to what it was a few years ago. The large users are frank in admitting that they will not be able again to purchase the product at the former low prices.

The outlet for casein is varied, owing to its large use in so many industries. The largest unlimited market is provided by jobbers who usually buy on contract from the creameries and resell to the consumers. In that way the creamery has a market with the least effort and the consumers can buy standardized lots of casein in quantities suited to their needs. However, by selling direct to the user the creamery can get more money for the casein and the cost to the user is less. Such a method, if it can be arranged properly, is the most satisfactory one for marketing. The development of such a market necessitates the production of a uniform quality of casein in satisfactory quantities.

The price it is possible to obtain depends upon the quality of the casein, market conditions, and the opportunity of making a satisfactory financial deal for the product. The market condition has much to do with the prevailing price. With a scarcity of casein on the market the buyers are willing to pay higher prices and are not nearly so critical as to the quality.

As the value of any casein is determined largely by its strength, the price received for buttermilk casein is less than that from skim milk, for the former is slightly weaker than the best grade of the latter. But with a short market a good grade of buttermilk casein may be sold easily at the ruling price of the skim-milk product.

The Grove City Creamery sells its buttermilk casein direct to the company that uses it at 1 or 2 cents under the prevailing price paid for a good grade of skim-milk casein. The company's chemist stated "The price they would be willing to pay would be governed by the market conditions. With a scarcity of casein the ruling price of skim-milk casein would be gladly paid." The company expressed its preference for the buttermilk casein sent in by the Grove City Creamery over that of some market grades of skim-milk casein.

The method of ascertaining the price paid for the casein in the form of pressed or cooked curd is on the basis of deducting from the market price of the dried casein the cost of transportation and expense of drying.

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